Announcements

- EXAMs will be returned ??
- Homework for tomorrow…

  Ch. 29: CQ 1, Probs. 2, 4, & 35

- Office hours…

  MW 10-11 am
  TR 9-10 am
  F 12-1 pm

- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm
  F 8-11 am, 2-5 pm
  Su 1-5 pm

Chapter 29

Potential & Field

(*Connecting Potential and Field & Sources of Electric Potential*)

29.1: Connecting Potential & Field

Force concepts

Energy concepts

$$\begin{tikzcd}
\vec{F} \arrow[d, leftrightarrow] & & U \arrow[d, leftrightarrow] \\
\vec{E} & & V
\end{tikzcd}$$

29.1: Connecting Potential & Field

Force concepts | *Energy* concepts

$$\begin{tikzcd} \vec{F} \arrow[rr, leftrightarrow] \arrow[d, leftrightarrow] & & U \arrow[d, leftrightarrow] \\ \vec{E} \arrow[rr, leftrightarrow] & & V \end{tikzcd}$$

29.1: Connecting Potential & Field

- *Electric potential* and *electric field* are NOT two distinct entities!
  - But rather two *different representations* of how source charges alter space around them.

$$W = \int_i^f \vec{F} \cdot d\vec{s} = -\Delta U$$

$$\therefore \Delta U = -\int_i^f \vec{F} \cdot d\vec{s}$$

$$\Delta U = q\Delta V$$

$$\vec{F} = q\vec{E}$$

$$q\Delta V = -\int_i^f q\vec{E} \cdot d\vec{s}$$

$$\Delta V = -\int_i^f \vec{E} \cdot d\vec{s}$$

29.1: Connecting Potential & Field

- *Electric potential* and *electric field* are NOT two distinct entities!
  - But rather two *different representations* of how source charges alter space around them.

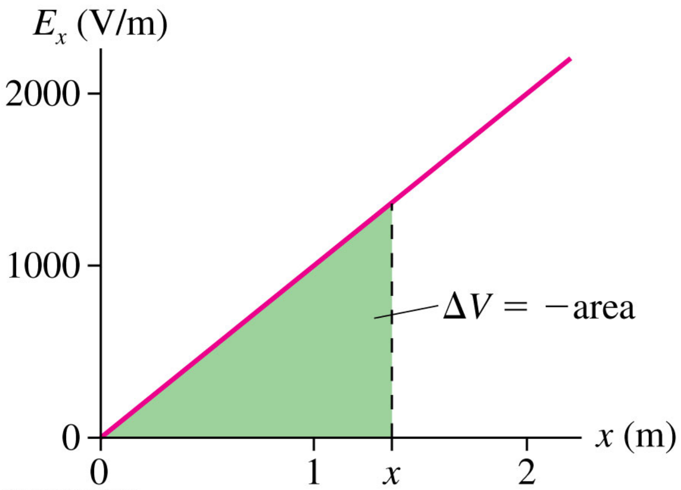
$$\boxed{\Delta V = -\int_i^f \vec{E} \cdot d\vec{s}}$$

- *Graphically:*
  - ΔV = *negative* of the area under the E vs. s curve between s_i & s_f

Ex. 29.1: Finding the Potential

The figure below is a graph of E_x, the x-component of the electric field, versus position along the x-axis.

Find and graph $V(x)$. Choose $V = 0\text{V}$ at $x = 0\text{m}$.



Graphically : The area under the curve

$A = \frac{1}{2}bh$

$x = 1\text{m}$, $E_x = 1000$ V/m

$x = 2\text{m}$, $E_x = 2000$ V/m

$x = x$, $E_x = (1000x)\,\frac{V}{m}$

$\frac{1}{2}(x\,\text{m})(1{,}000\ \text{V/m}) = (500x^2)\,\text{V}$

$V(x) = -500x^2\ \text{V}$

Ex. 29.1: Finding the Potential

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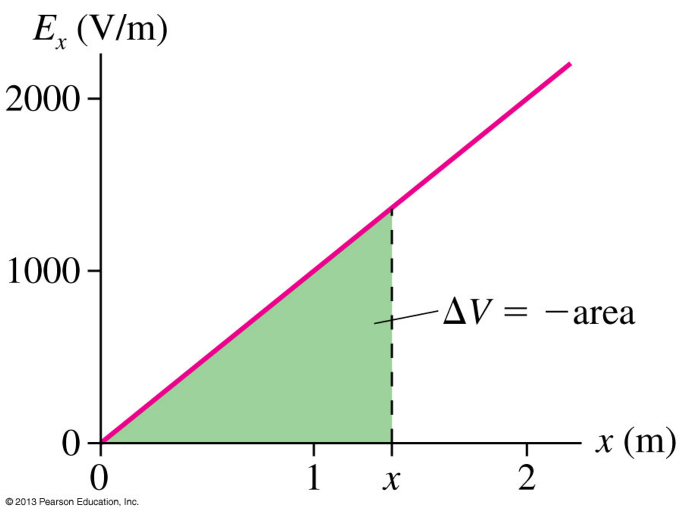
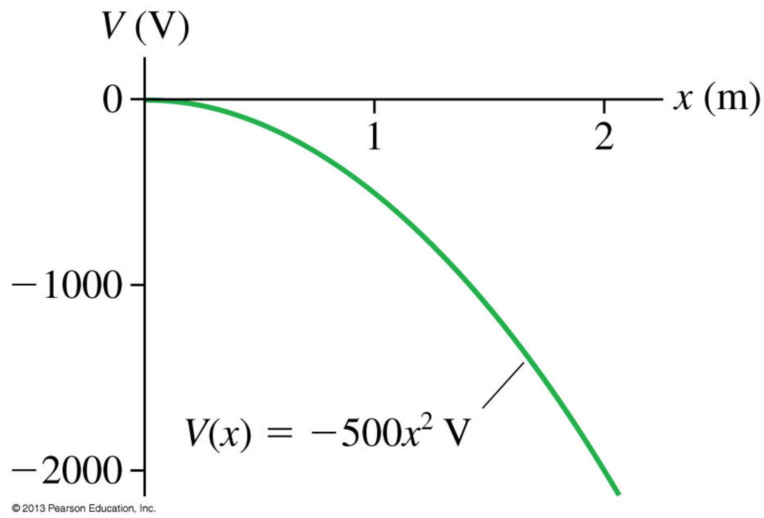




Solution Curve

$\vec{E} = (1\times10^3 x)\frac{V}{m}\hat{i}$

$d\vec{s} = dx\,\hat{i}$

$\vec{E}\cdot d\vec{s} = (1000x)\,dx\,(\hat{i}\cdot\hat{i}) = 1000x\,dx$

$\Delta V = V(x) - V(0) = -\int_0^x 1{,}000\,dx = -1000\int_0^x x\,dx$

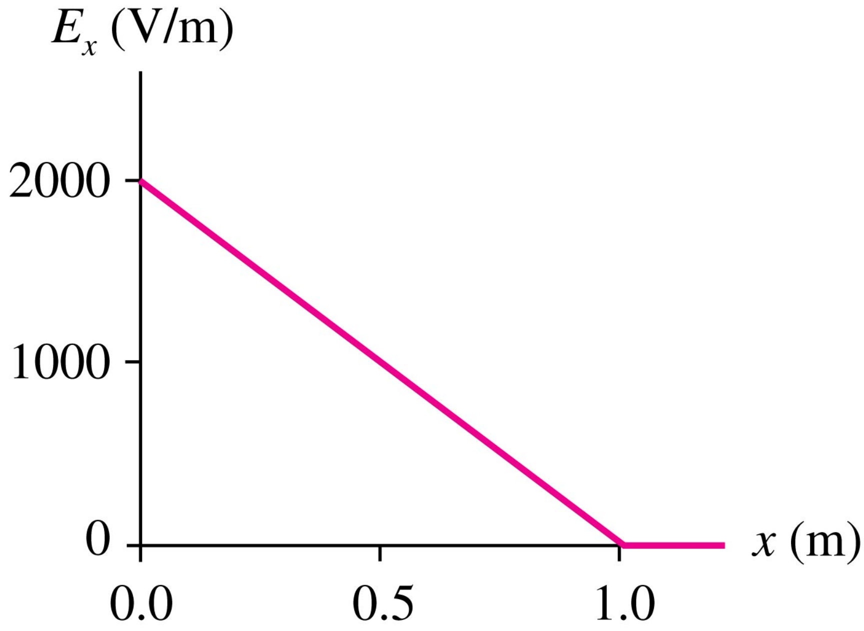
$= -500x^2$

Quiz Question 1

This is a graph of the x-component of the electric field along the x-axis. Choose the potential to be zero at the origin.

What is the potential at x = 1m?

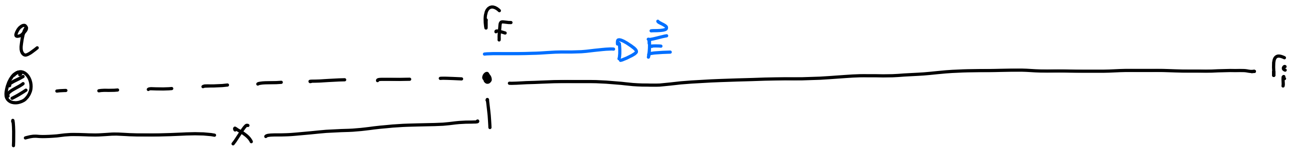
1. 2000V
2. 1000V
3. 0V
4. -1000V
5. -2000V



Connecting *V* & *E* for a point charge…

i.e. Use the *E*-field of a point charge to find its electric potential..

Bring in a point from $r_i = \infty$ to $r_f = r$



$$\vec{E} = \frac{Kq}{x^2}\hat{i} \qquad \therefore\ \vec{E}\cdot d\vec{s} = \frac{Kq}{x^2}dx$$

$$d\vec{s} = dx\,\hat{i}$$

$$\Delta V = -\int_{r_i}^{r_f} \frac{Kq}{x^2}dx = -Kq\int_{\infty}^{r} x^{-2}dx = Kq\,x^{-1}\Big|_{0}^{r}$$

$$V(r) = \frac{KQ}{r}$$

Ex. 29.2:
The potential of a parallel-plate capacitor

Find the electric potential inside the capacitor. Let V=0V at the negative plate.

$$\vec{E} = \frac{\eta}{\epsilon_0} = \frac{Q}{A\epsilon_0} \quad \therefore \quad \vec{E} = \frac{-Q}{\epsilon_0 A}\hat{j} = -E\hat{j}$$

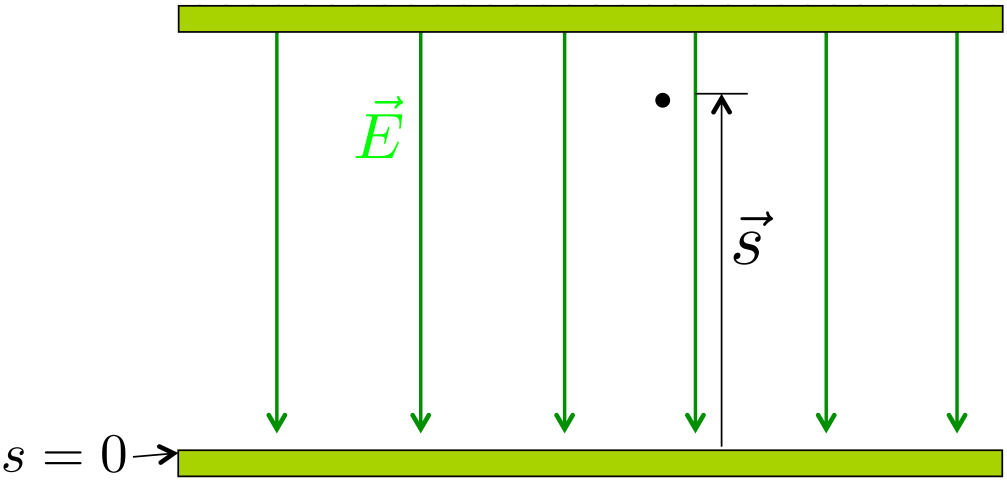
$$d\vec{s} = dy\hat{j}$$

$$= -E\,dy$$

$$\Delta V = -\int_i^f -\vec{E}\cdot dy$$

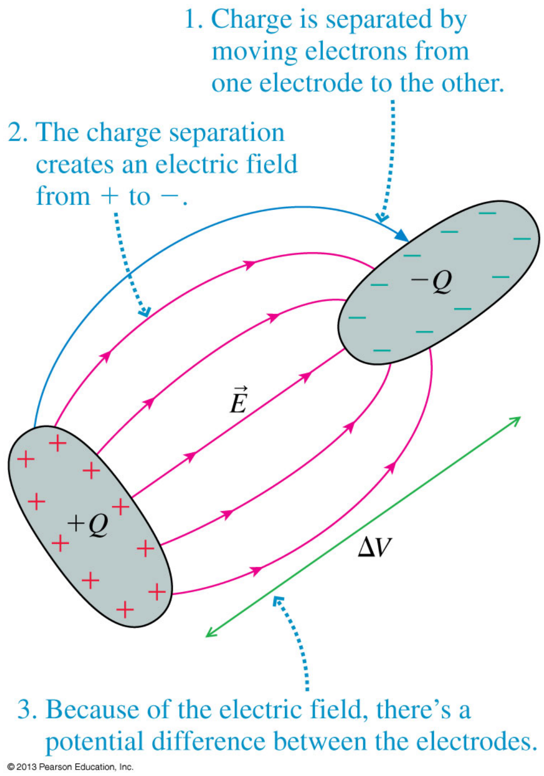
$$\vec{E}\int_0^s dy$$

$$\Delta V = ES$$



29.2:
Sources of Electric Potential

A *separation of charge* creates an *electric potential difference*!



Ways to separate charge:

1. Rub feet on carpet
2. Van de Graaff generator
3. Batteries

Batteries and emf

- Batteries use chemical reactions to “lift” positive charges to the positive terminal.
  - Battery provides the energy to do the work required.

- The emf of the battery is the *work done per charge*.

$$\boxed{\Delta V_{bat} = \frac{W_{chem}}{q} = \mathcal{E}} \quad \text{(ideal battery)}$$

- where ΔV_{bat} is the *terminal voltage*.